A country from Eastern Europe with the average annual temperature of 10^0C.

5.3. Manure management (CRF 3.B)

5.3.1. CH_4 emissions from manure management

CH_4 is produced from the decomposition of the organic matter remaining in the manure under anaerobic conditions. CH_4 emission rates from Manure management directly depend on the manure management system and temperature.

The total CH_4 emissions from livestock manure management was 2.62 kt, where the largest contributor in 2023 to the CH_4 emissions in manure management was the cattle livestock (Table 5.1). The total CH_4 emissions from livestock manure management declined by more than 45% by 2023 in comparison with the base year.

CH_4 emissions from manure management is identified to be a key.

Table 5.1. CH_4 emissions from Manure management in 1990–2023, kt

Year	Cattle	Swine	Sheep	Goats	Horses	Poultry	Fur animals	Rabbits	Total
1990	1.80	2.58	0.03	0.0003	0.013	0.12	0.16	0.007	4.71
1995	1.71	2.40	0.03	0.0003	0.012	0.10	0.16	0.007	4.41
2000	1.49	1.62	0.03	0.0002	0.010	0.08	0.14	0.008	3.38
2005	1.19	1.27	0.02	0.0002	0.008	0.06	0.12	0.008	2.67
2006	1.10	1.38	0.01	0.0002	0.008	0.05	0.10	0.007	2.66
2007	0.98	1.35	0.01	0.0003	0.007	0.05	0.09	0.006	2.49
2008	0.93	0.90	0.01	0.0002	0.007	0.04	0.04	0.005	1.92
2009	0.92	0.92	0.01	0.0003	0.007	0.04	0.06	0.004	1.96
2010	0.89	0.98	0.01	0.0003	0.006	0.04	0.06	0.004	1.99
2011	0.76	0.86	0.01	0.0004	0.006	0.04	0.05	0.003	1.72
2012	0.75	0.90	0.01	0.0005	0.007	0.04	0.03	0.005	1.74
2013	0.78	1.04	0.01	0.0005	0.009	0.05	0.04	0.008	1.93
2014	0.83	1.02	0.01	0.0007	0.008	0.05	0.05	0.007	1.98
2015	0.96	1.03	0.01	0.0005	0.009	0.05	0.07	0.006	2.14
2016	1.04	1.02	0.01	0.0005	0.008	0.05	0.07	0.004	2.20
2017	1.10	1.04	0.01	0.0004	0.007	0.05	0.09	0.007	2.30
2018	1.16	1.04	0.01	0.0005	0.008	0.04	0.07	0.006	2.34
2019	1.19	1.14	0.02	0.0006	0.008	0.04	0.08	0.005	2.48
2020	1.25	1.09	0.02	0.0005	0.008	0.04	0.06	0.004	2.48
2021	1.28	1.10	0.02	0.0006	0.008	0.04	0.07	0.004	2.52
2022	1.35	1.12	0.02	0.0006	0.011	0.05	0.07	0.003	2.62
2023	1.36	1.10	0.02	0.0006	0.010	0.05	0.08	0.003	2.62

Table 5.2. Annual average livestock population in 1990–2023 by categories, 1000 heads

Year	Dairy cattle	Mature non-dairy cattle	Growing animals	Swine	Sheep	Goats	Horses	Poultry	Rabbits	Fur-bearing animals
1990	280.7	51.2	424.0	859.9	158.5	2.1	8.6	5,597.2	86.0	230.8
1995	264.3	51.0	391.1	798.6	161.8	2.2	7.8	4,671.7	91.0	230.8
2000	253.4	41.5	318.2	541.1	141.4	1.3	6.6	3,593.1	96.1	202.8
2005	226.7	27.4	208.7	424.3	94.4	1.3	5.2	2,838.0	96.4	174.8
2006	211.4	23.2	183.8	459.8	68.9	1.7	5.0	2,461.3	81.3	146.8
2007	185.4	20.1	164.3	448.8	55.4	2.0	4.6	2,273.6	75.0	131.8
2008	171.6	18.8	152.1	298.4	43.2	1.9	4.2	1,838.9	56.5	55.0
2009	167.7	17.7	139.7	306.3	38.9	2.0	4.2	1,754.6	47.5	89.7
2010	158.6	16.4	131.9	326.4	33.0	2.4	3.9	2,081.7	49.9	92.3
2011	138.4	15.6	112.8	285.7	32.4	3.1	3.9	1,797.5	41.2	73.8
2012	131.0	15.2	105.9	300.2	33.3	3.7	4.2	1,672.6	60.1	50.5
2013	128.6	12.4	118.7	345.0	33.1	4.2	5.5	2,121.7	104.3	62.0
2014	115.6	11.6	125.1	340.8	34.9	5.5	5.3	2,195.3	88.9	78.9
2015	116.8	13.3	125.1	344.6	35.4	4.1	5.8	2,381.8	73.5	98.0
2016	116.5	13.3	117.3	340.1	48.7	3.6	5.1	2,498.9	52.5	101.4
2017	112.8	12.8	119.1	346.5	55.4	3.1	4.8	2,063.8	83.5	126.0
2018	108.4	12.8	117.6	345.8	68.6	3.6	4.9	2,017.1	72.9	103.7
2019	103.0	13.4	115.6	379.0	81.1	4.5	5.3	1,759.2	62.3	118.8
2020	100.4	16.7	112.6	364.9	90.2	4.2	5.3	2,010.2	53.2	91.2
2021	96.7	16.3	111.4	365.1	91.2	4.6	5.4	2,086.3	44.1	103.6
2022	96.5	17.3	110.4	371.7	95.8	5.0	6.8	2,216.4	35.0	100.3
2023	96.2	17.7	109.9	365.7	94.0	4.8	6.5	2,440.6	33.6	111.6

5.3.1.1. Cattle manure management

Methodology, data availability, data sources, and emission factors

CH_4 production from manure produced by dairy cattle and non-dairy cattle was estimated using the tier 2 approach (equations 10.22–10.24) of the 2006 IPCC GLs and using the country-specific data and the IPCC default factors (Table 5.4). The calculation algorithm and the performance parameters used to estimate GEI for the whole period have been reported in 'Enteric fermentation' section. However, the GEI values have been duplicated in Table 5.3.

Table 5.3. Gross Energy Intake by cattle in 1990–2023, MJ/day

year	Dairy cattle	Mature non-dairy cattle	Growing animals
1990	239.0	140.8	101.9
1995	233.9	141.6	102.2
2000	222.4	141.1	102.0
2005	217.7	142.1	102.4
2006	221.0	143.9	102.9
2007	225.0	142.8	102.6
2008	232.0	144.8	103.3
2009	242.0	142.8	102.6
2010	248.8	142.5	102.5
2011	241.3	143.1	102.7
2012	254.4	141.7	102.2
2013	267.1	143.4	102.8
2014	266.4	142.9	102.6
2015	267.7	143.3	102.8
2016	275.8	143.0	102.6
2017	283.7	142.9	102.6
2018	292.8	142.8	102.6
2019	297.3	142.7	102.6
2020	304.0	141.2	102.1
2021	305.8	143.0	102.7
2022	309.7	145.6	103.5
2023	313.0	143.2	102.7

Table 5.4. Parameters used to estimate VSs

Cattle category	Bo[1,2] m^3 CH_4/kg VS
Mature cattle	
...Dairy	0.24
...Non-dairy cattle:	
……Mature females	0.17
……Mature males	0.17
Growing animals	0.17

[1] IPCC 2006, Vol.4, Ch.10: Emissions from Livestock and Manure Management, Table 10A-4, p.10.77–78.
[2] IPCC 2006, Vol. 4, Ch.10: Emissions from Livestock and Manure Management. Dairy Cows – Table 10A.1 and 10A.4, pp. 10.72, 10.77; Other Cattle – Table 10A.2 and 10 A.5, pp. 10.73,10.7 (for Eastern European countries).

Cattle manure management systems

The data on MMS allocation to store manure generated by dairy cattle is presented in Table 5.5. It was evaluated that the changes in the management of dairy-cattle manure followed the changes in dairy-cattle housing practices, namely, the transition from tie-stall housing technology to loose-technology with slatted floors.

Table 5.5. MMS usage, methane conversion factors (MCFs) for dairy cattle in 1990–2023

year	Manure management system, %		
	Liquid/slurry	Solid storage	Pasture/range
1990	0%	56%	44%
1995	0%	56%	44%
2000	0%	56%	44%
2005	0%	56%	44%
2006	0%	56%	44%
2007	0%	56%	44%
2008	0%	56%	44%
2009	0%	56%	44%
2010	0%	56%	44%
2011	0%	56%	44%
2012	0%	56%	44%
2013	0%	56%	44%
2014	4%	52%	44%
2015	8%	51%	41%
2016	10%	49%	41%
2017	13%	47%	41%
2018	15%	44%	41%
2019	17%	42%	40%
2020	19%	40%	40%
2021	22%	38%	40%
2022	24%	36%	40%
2023	24%	36%	40%
MCFs[3], %	10	2	1

It was assumed that the data on MMS usage practice for mature non-dairy cattle has not changed over the whole period of reporting – tie stall housing technology with solid storage MMS was mostly applied in cattle breeding holdings. Moreover, it was assumed that about 50% of time, mature non-dairy cattle spent on pasture. Thus, a share of non-dairy cattle manure stored to solid storage MMS made up 50% over the entire reporting period. The data on MMS practice for growing cattle animals was assumed to be 56% of manure generated is stored in solid MMS and 44% is dropped during animal grazing.

Quantitative overview – CH_4 emissions from cattle manure management

The total CH_4 emissions from cattle manure management systems were 1.36 kt in 2023 (Table 5.6).

[3] IPCC 2006 Volume 4 Chapter 10: Emissions from Livestock and Manure Management, Table 10.17, p.10.45.

Table 5.6. CH_4 emissions from cattle manure management activities in 1990–2023, kt

Year	Dairy cattle	Non-dairy cattle	Growing cattle	Total emissions
1990	1.13	0.09	0.57	1.80
1995	1.05	0.13	0.53	1.71
2000	0.95	0.10	0.43	1.49
2005	0.83	0.07	0.28	1.19
2006	0.79	0.06	0.25	1.10
2007	0.71	0.05	0.22	0.98
2008	0.67	0.05	0.21	0.93
2009	0.69	0.05	0.19	0.92
2010	0.67	0.05	0.18	0.89
2011	0.56	0.04	0.15	0.76
2012	0.56	0.04	0.14	0.75
2013	0.58	0.04	0.16	0.78
2014	0.63	0.03	0.17	0.83
2015	0.75	0.04	0.17	0.96
2016	0.84	0.04	0.16	1.04
2017	0.90	0.04	0.16	1.10
2018	0.96	0.04	0.16	1.16
2019	0.99	0.04	0.16	1.19
2020	1.04	0.06	0.15	1.25
2021	1.07	0.06	0.15	1.28
2022	1.14	0.06	0.15	1.35
2023	1.15	0.06	0.15	1.36

5.3.1.2. Other livestock manure management

Methodology, data availability, data sources and emission factors

CH_4 emissions from storage and treatment of manure produced by other livestock were calculated using equation 10.22 of the 2006 IPCC Guidelines (equation 5.1).

$$CH_{4Manure} = \sum_{(T)} \frac{\left(EF_{(T)} \bullet N_{(T)}\right)}{10^6}$$

equation 5.1.

$CH_{4Manure}$ = CH_4 emissions from manure management, for a defined population, kt CH_4 yr^{-1}

$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head_{-1}$ yr^{-1} (Table 5.7)

$N_{(T)}$ = the number of head of livestock species/category *T* in the country (Table 5.2)

T = species/category of livestock

The data on MMSs for sheep, goats and horse was developed based on grazing-period of animals in the Party ABC. It was assumed that for all livestock categories, except swine, manure is stored and treated in solid MMS (Table 5.7)

Table 5.7. The data on MMS usage and methane EFs from manure management

Livestock category	Manure management system, %[4]			EF[5], kg CH_4/head/year
	Liquid systems	Solid storage	Pasture/ Range	
Swine	65	30	5	3
Sheep		51	49	0.19
Goats		51	49	0.13
Horses		60	40	1.56
Poultry		99.5	0.5	
...Broilers				0.02
...Layers and other chickens				0.03
...Other Poultry				0.055
Fur animals		100	-	
…Foxes and raccoon				0.68
…Minks				0.68
Rabbits		100	-	0.08

Quantitative overview – CH_4 emissions from manure management of other livestock

The total CH_4 emissions from manure management system for other livestock categories were 1.25 kt in 2023 (Figure 5.1).

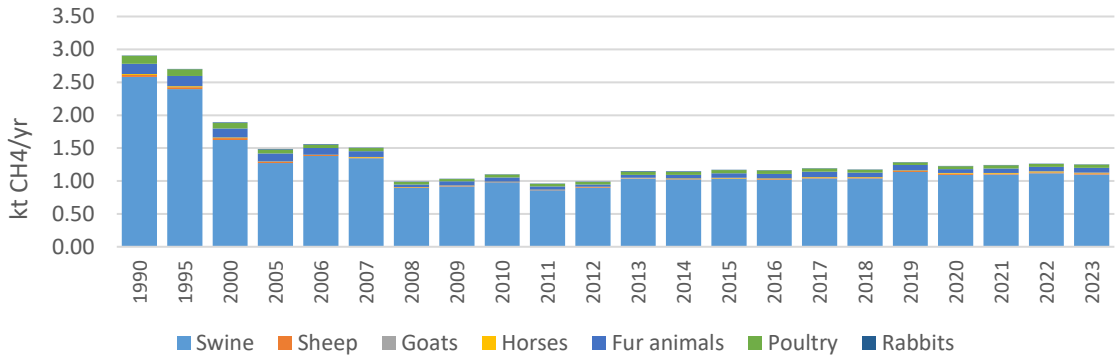

Figure 5.1. CH_4 emissions from other livestock MMSs in 1990–2023, kt

[4] The module was applied only in the estimation of N_2O emissions from manure management of other livestock, since CH_4 emission from manure management was estimated based on *Tier 1* of the IPCC Guidelines.
[5] IPCC 2006, Vol.4, Ch.10: Table 10A.7
Table 10.14. Manure management methane emission factors by temperature for cattle, swine, and buffalo.
Table 10.15. Manure management methane emission factors by temperature for sheep, goats, camels, horses, mules and asses, and poultry
Table 10.16. Manure management methane Emission Factors for Deer, Reindeer, Rabbits, and Fur-bearing animals.

5.3.2. Direct N_2O emissions from manure management

5.3.2.1. Cattle manure management

Methodology, data availability, data sources and emission factors

A tier 2 approach was applied to estimate direct and indirect N_2O emissions from cattle manure management (equations 10.30–10.33 of the 2006 IPCC GLs). The performance parameters reported and desribed in 'Enteric Fermentation' section were used to calculate GEI of dairy and non-dairy cattle and Nex rates for dairy and non-dairy cattle. Moreover, country-specific values of crude protein content in feed consumed and in milk was employed. Nex rates are reported in Table 5.8.

Table 5.8. Nex rates for dairy cattle and non-dairy cattle in 1990-2023, kg N/head/day

Year	Dairy cattle	Mature non-dairy cattle	Growing cattle
1990	84.7	47.2	29.8
1995	83.2	47.5	31.4
2000	80.9	47.3	31.4
2005	79.9	47.7	31.6
2006	80.6	48.2	31.1
2007	81.6	48.0	30.2
2008	84.2	48.7	30.7
2009	87.0	48.0	30.9
2010	88.7	47.9	30.5
2011	94.2	48.6	31.2
2012	88.5	47.3	30.7
2013	100.3	48.4	30.4
2014	100.7	48.0	32.1
2015	100.8	47.0	31.2
2016	102.8	47.9	31.9
2017	104.6	46.6	31.9
2018	107.6	48.2	32.1
2019	108.1	47.9	32.3
2020	109.8	47.6	30.9
2021	110.5	47.7	31.7
2022	111.5	48.7	32.1
2023	111.8	47.8	31.8

Quantitative overview – Nitrogen excretion by cattle livestock

The total quantity of nitrogen generated by cattle was 15,089 tonnes in 2023. The allocation of nitrogen stored across different types of MMS is presented in Table 5.10.

Table 5.10. The allocation of the quantity of nitrogen (in manure) excreted by cattle, 1000 kg

Year	Liquid system	Solid storage	Pasture range and paddock	Total nitrogen
1990	0	20,924	17,903	38,827
1995	0	19,782	16,917	36,699
2000	0	17,467	14,972	32,439
2005	0	13,978	12,041	26,019

Year	Liquid system	Solid storage	Pasture range and paddock	Total nitrogen
2006	0	12,812	11,049	23,860
2007	0	11,306	9,753	21,058
2008	0	10,756	9,281	20,037
2009	0	10,600	9,159	19,759
2010	0	10,125	8,752	18,877
2011	0	9,287	8,039	17,325
2012	0	8,345	7,221	15,567
2013	0	9,174	7,925	17,099
2014	463	8,249	7,494	16,207
2015	945	8,102	7,250	16,297
2016	1,236	7,874	7,251	16,361
2017	1,489	7,564	7,149	16,201
2018	1,738	7,258	7,056	16,053
2019	1,915	6,797	6,791	15,503
2020	2,149	6,464	6,683	15,296
2021	2,329	6,140	6,526	14,995
2022	2,593	5,989	6,573	15,154
2023	2,590	5,954	6,544	15,089

5.3.2.2. Other livestock

Methodology, data availability, data sources and emission factors

The activity data on other livestock populations have been obtained from the national statistics (Table 5.2); the data on MMS allocation is reported in Table 5.7; the values of Nex rates were used from the 2006 IPCC GLs (Table 5.11).

Table 5.11. Nitrogen excretion rates per head of animal, kg N/head/day

Livestock category[6]	Nitrogen excretion rate, kg N/head/day
Swine	10.0
Poultry	
...Layers (1.8 kg)	0.39
...Broilers (0.9 kg)	0.36
...Other chickens (1.8 kg)	0.54
...Other poultry (4.75 kg)	1.36
Sheep (65 kg)	21
Goats (40 kg)	19
Horses (550 kg)	60

Quantitative overview – Nitrogen excretion by other livestock

The total amount of nitrogen generated by other livestock was 4,315 tonnes in 2023 (Table 5.12).

[6] IPCC 2006, Vol.4, Ch.10: Emissions from Livestock and Manure Management, Table 10.19, p.59; average weight Table 10A-9, p.10.82.

Table 5.12. Nitrogen (in manure) excreted by other livestock categories, 1000 kg N/year

Year	Livestock category						Total
	Sheep	Goats	Horses	Poultry	Fur-bearing animals	Rabbits	
1990	3,328	40	516	2,281	1,698	696	8,560
1995	3,398	42	468	1,929	1,698	737	8,273
2000	2,969	24	396	1,465	1,572	778	7,205
2005	1,982	24	312	1,122	1,445	781	5,667
2006	1,447	33	300	973	1,319	658	4,730
2007	1,162	38	276	882	1,305	608	4,271
2008	907	35	252	720	559	457	2,930
2009	818	38	252	685	980	385	3,156
2010	692	46	234	802	967	404	3,146
2011	680	60	234	692	812	334	2,812
2012	699	71	252	652	559	487	2,720
2013	695	80	330	847	618	845	3,414
2014	733	104	318	859	711	720	3,446
2015	743	77	348	915	771	595	3,450
2016	1,022	69	306	961	787	425	3,571
2017	1,164	59	288	798	870	676	3,856
2018	1,440	69	294	786	722	591	3,901
2019	1,703	85	318	690	836	505	4,138
2020	1,894	79	318	786	514	431	4,021
2021	1,915	88	324	824	573	357	4,081
2022	2,011	95	408	875	555	283	4,227
2023	1,973	92	390	971	617	272	4,315

5.3.2.3. Quantitative overview – Direct N_2O emissions from livestock and poultry

The total N amount produced by livestock and stored in solid, liquid and deep litter types of MMSs was 15,161 kt in 2023 (Table 5.14).

The estimates of direct N2O emissions were conducted based on the amount of nitrogen (in manure) is generated and stored in MMSs and the default IPCC N_2O EFs relevant for each type of MMS (Table 5.13).

The total direct N_2O emissions was 0.08kt in 2023 (Table 5.14). The decrease in N_2O emissions was due to the decline in livestock population number and the changes occurred in MMS practice.

Table 5.13. EFs for direct N_2O emissions from manure management

Manure management system	EF_3 (kg N_2O-N/kg Nitrogen excreted)
Liquid system (without natural crust cover)	0
Solid storage	0.005

Table 5.14. Total nitrogen (in manure) excreted by livestock and direct N_2O emissions from MMSs in 1990–2023

year	Nitrogen excreted, tonnes				N_2O emissions, kt		
	Liquid/ Slurry	Solid storage	Pasture, Range	Total	Liquid/ Slurry	Solid storage	Total
1990	5,589	30,195	20,201	55,986	0	0.237	0.237
1995	5,191	28,568	19,198	52,958	0	0.224	0.224
2000	3,517	24,662	16,875	45,054	0	0.194	0.194
2005	2,758	19,804	13,367	35,929	0	0.156	0.156
2006	2,989	18,070	12,129	33,188	0	0.142	0.142
2007	2,917	16,220	10,680	29,817	0	0.127	0.127
2008	1,940	14,015	9,996	25,951	0	0.110	0.110
2009	1,991	14,152	9,835	25,978	0	0.111	0.111
2010	2,122	13,790	9,375	25,287	0	0.108	0.108
2011	1,857	12,497	8,641	22,995	0	0.098	0.098
2012	1,951	11,484	7,853	21,288	0	0.090	0.090
2013	2,243	13,107	8,613	23,963	0	0.103	0.103
2014	2,678	12,176	8,207	23,060	0	0.096	0.096
2015	3,185	12,039	7,968	23,192	0	0.095	0.095
2016	3,447	11,803	8,083	23,333	0	0.093	0.093
2017	3,741	11,740	8,041	23,521	0	0.092	0.092
2018	3,986	11,336	8,090	23,412	0	0.089	0.089
2019	4,379	11,065	7,988	23,431	0	0.087	0.087
2020	4,521	10,482	7,963	22,966	0	0.082	0.082
2021	4,702	10,201	7,824	22,727	0	0.080	0.080
2022	5,009	10,132	7,958	23,098	0	0.080	0.080
2023	4,967	10,194	7,900	23,061	0	0.080	0.080

5.3.3. Indirect N_2O emissions from Manure management

Indirect N2O emissions from manure management have been identified as a key category by level and trend.

N losses due to volatilization from manure management

a Tier 1 method (equations 10.26-10.27) of the 2006 IPCC GLs was applied to estimate indirect N_2O emissions from manure management due to volatilization.

N losses due to leaching from manure management systems

a Tier 2 methodology (equations 10.28-10.29) for estimation of N losses due to leaching from manure management systems is applied.

Table 5.15. EFs, $Frac_{Leach}$ and $Frac_{GasMS}$ used in the estimates

Animal type	**MMS**	**$Frac_{GasMS}$**[7]
Swine	Liquid/slurry	48%
	Solid storage	45%
Dairy cow	Liquid/slurry	40%

[7] Table 10.22 of Chapter 10, Volume 4 of the 2006 IPCC Guidelines

Animal type	MMS	$Frac_{GasMS}$[7]
	Solid storage	30%
Poultry	Poultry with litter	55%
Other cattle	Solid storage	45%
Othes	Solid storage	12%
$Frac_{LeachMS}$	Solid storage	3%[8]
EF_4		0.01[9]
EF_5		0.0075[9]

Quantitative overview – Indirect N_2O emissions from MMSs

The total indirect N_2O emissions from MMS was 0.182 kt in 2023 (Table 5.16). The decrease in indirect N_2O emissions from MMSs was due to the changes occurred in dairy cattle MMS practices and the decline in the livestock population.

Table 5.16. Indirect N_2O emissions from Manure management 1990–2023, kt

Year	N losses due to volatilization from MMSs, kt N_2O	N losses due to leaching from MMSs, kt N_2O	Total indirect emissions from MMSs, kt N_2O
1990	0.207	0.219	0.426
1995	0.193	0.205	0.399
2000	0.156	0.166	0.322
2005	0.122	0.130	0.252
2006	0.115	0.123	0.238
2007	0.105	0.112	0.217
2008	0.088	0.094	0.182
2009	0.088	0.093	0.181
2010	0.087	0.093	0.180
2011	0.078	0.084	0.162
2012	0.074	0.079	0.153
2013	0.084	0.090	0.174
2014	0.083	0.088	0.171
2015	0.086	0.091	0.177
2016	0.086	0.092	0.178
2017	0.086	0.092	0.178
2018	0.086	0.092	0.178
2019	0.087	0.092	0.179
2020	0.086	0.091	0.177
2021	0.086	0.091	0.177
2022	0.088	0.093	0.181
2023	0.088	0.093	0.182

[8] Let's assume that the Party has provided *a full citation to the paper used as a reference source provided*. And stated that the value corresponds to the typical range of 1–20% provided by the 2006 IPCC GLs.

[9] Table 11.3 of Chapter 11 of Volume 4 of the 2006 IPCC Guidelines

5.3.4. Category-specific QA/QC and verification

The quality objectives and the QA/QC plan for Party's GHG inventory at the national level are presented in Chapter 1.2.

5.3.5. Category-specific recalculations

No recalculations completed.

5.3.6. Category-specific planned improvements

There are no planned category-specific improvements.